An Acoustic Study on Glottalized Vowels in the Yi (Lolo) Language : A Preliminary Report

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—A Preliminary Report—

Masatake DANTSUJI

O. Purpose

The aim of the present study is to examine the acoustic cues which can discriminate glottalized vowels from non-glottalized ones in the Yi (Lolo) Language. The opposition between glottalized and non-glottalized vowels is a characteristic phenomenon in the language and the clarification in terms of acoustic dimentions can be of considerable interest. There has been almost no report on the acoustic features in Yi vowel systems. In this present study, it is intended to examine the acoustic characteristics of glottalized /non-glottalized vowels based on a series of spectrographic analysis.

I. Introduction

Yi (彝) is a language mainly spoken in the Southwestern part of China, Yunnan (雲南), Sichuan (四川), Guizhou (貴州) Provinces, and Xi-de (喜徳) dialect of Sichuan is regarded as the standard Yi.[1] It is pointed out Xi-de Yi has two types of vowel series. Xi-de Yi has ten vowels in phonemic inventory in all. Five of them can be specified as non-glottalized vowels (/i, ɯ, o, u, ɿ/), while the rest as glottalized vowels (/e̠, a̠, ɔ̠, u̠, ɿ̠/). Glottalized vowels in Yi have a function to delete the final consonant. From a comparative linguistic point of view, it can be inferred that the final stop was modified and the form of –VC[stop] was contracted to be glottalized vowel. It is pointed out that the tongue height of glottalized vowels is generally lower than that of non-glottalized ones, and it is auditorily easy for a listener to distinguish glottalized vowels from non-glottalized ones (Nishida, 1979).

Because of lack of data, the literature on the acoustic study of glottalized vowel is quite limited in quantity and quality. As was mentioned above, the phonetic study of the general distinction between glottalized and non-glottalized vowels has been of considerable interest, but no previous report has been of the distinction in

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1) Nishida (1979) classifies the dialects of the Yi Language in six groups as the North, the East, the South, the West, the Southeast and the Central Dialects. The Xi-de dialect belongs to the North group.

Lolo, especially in acoustic dimention. The present study is intended to explore, as a preliminary study, the acoustic characteristics of the distinction, hoping to establish articulatory-acoustic criteria on glottalized-nonglottalized vowels. Five types of spectrographic analysis were made; wide-band analysis, narrow-band analysis, contour display analysis, amplitude analysis and section analysis. For the purpose of supplemental examination, Visi Pitch was used in order to scan fundamental frequency (Fo) and amplitude.

2. METHOD AND PROCEDURES

The materials are constructed from ten vowels pronounced in isolation and seventy-nine words including these vowels in various phonetic environments. All recordings of these materials were made by Prof. T. Nishida at the College of Southwest Tribes in China[2] (西南民族学院). The informant was one adult female, who was a lecturer of the college.

In the Xi-de dialect of Yi there are four contrastive tones.

e.g.	high	/ɕi 55/	'to bite'
	mid-high	/ɕi 44/	'what'
	mid	/ɕi 33/	'to arrive'
	low	/ɕi 21/	'such'

The difference of these tones can, of course, be represented in the fundamental frequency of vowels. It is generally said that the variations of fundamental frequency little affect the formant structure. By the preliminary analysis, however, it was observed that the difference of tone has a great influence on the formant structure of vowels. Therefore the analysis of glottalized/non-glottalized vowels was mainly made on the vowels carrying mid tone /33/, since mid tone is considered to be neutral one.

Five types of spectrographic analysis as mentioned above were made for the following examination. From the wide-band analysis, the formant structure of a given vowel can be examined. As the narrow-band analysis gives the harmonic structure, it is useful to study pitch and intonation. Contour display analysis is used for determining formant frequencies and for scanning relative intensity of formant structure. Amplitude display shows the overall intensity of the speech sounds as a continuous function of time. From the section analysis, it is possible to study the internal structure of the formant and relative intensity of harmonic components.

2) Recording was made on January 17, 1981.

3. Results and Discussion

3.1 Formant Structure

The frequencies of the first and second formants are generally considered to indicate the relative vowel quality. It is generally known that the frequency of the first formant (F1) is related with the relative height of tongue. The difference between the first and second formants reflects the degree of backness (Ladefoged, 1975).

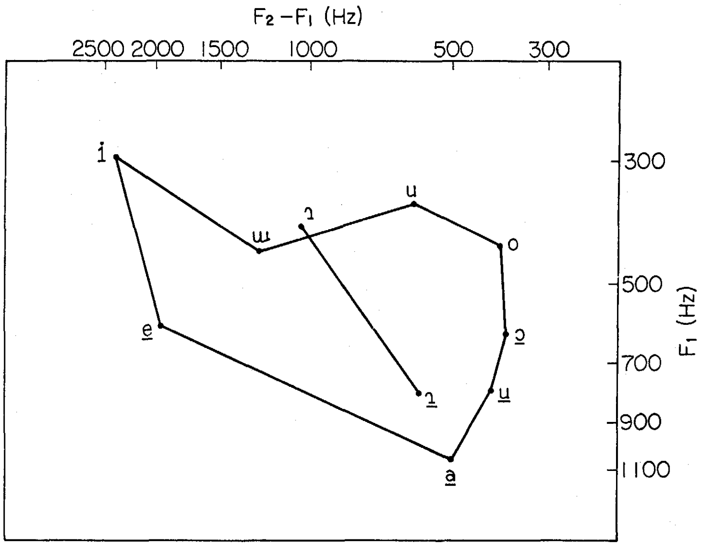


Fig. 1. The formant chart of the vowels of Xi-de Yi, pronounced in isolation.

Table 1. The mean value and standard deviation of the frequency of F_1 and F_2 of ten vowels carrying mid-tone /33/ in word contexts.

	Vowel	F_1		F_2	
		Mean (Hz)	SD (Hz)	Mean (Hz)	SD (Hz)
non-glottalized	/i/	311. 3	40. 8	2, 542. 5	192. 1
	/ɯ/	490. 0	61. 1	2, 051. 7	259. 3
	/o/	340. 0	53. 5	860. 0	188. 3
	/u/	326. 7	107. 2	1, 043. 3	185. 1
	/ɿ/	353. 3	96. 0	2, 023. 3	363. 8
glottalized	/e̲/	666. 7	58. 8	2, 243. 3	92. 0
	/a̲/	1, 024. 7	80. 0	1, 608. 7	60. 0
	/ɔ̲/	737. 1	120. 3	1, 280. 0	200. 9
	/u̲/	635. 7	104. 6	1, 175. 7	88. 5
	/ɿ̲/ [3)]	620. 0	0	1, 680. 0	0

3) There was only one example of the vowel /ɿ̲/.

Figure 1 shows the acoustic parameters of vowel quality analyzed from ten vowels pronounced in isolation. The frequency of the first formant is plotted on the ordinate, and the difference between the frequency of the second and first formant is plotted on the abscissa. Table 1 shows the mean value and standard deviation of the frequencies of first and second formants of ten vowels having mid tone in word contexts.

From the formant chart, it can be considered that the vowels tend to concentrate in back of the tongue position, if articulatory and acoustic dimensions coincide with each other. Therefore, it appears that the vowel system of Xi-de Yi utilizes not only the opposition of the tongue advancement and height but also the opposition of lip rounding and retroflexion (The College of the Southwest Tribes ed., 1979). It can be said that the opposition between glottalized and non-glottalized vowels becomes more prominent in this position. Therefore, it is plausible to limit the domain of analysis within the opposition between /u̱/ and /u/ and between /ɔ̱/ and /o/. The opposition between /ɿ/ and /ɿ̱/ is excluded here because of lack of materials.

Another point that the formant structure indicates is that the frequency of the first formant of glottalized vowels is higher than that of non-glottalized vowels. It is genrally known that the frequency of the first formant can be influenced by several articulatory factors and it is inversely related to the tongue height. It can be inferred, therefore, that the tongue height of glottalized vowels is lower than that of non-glottalized ones. Then this would confirm Nishida's remark on tongue height of Lolo vowels. From Figure 1 and Table 1, it can be said that the frequency of the first formant is over 500 Hz. However, this absolute value (500 Hz) of boundary between glottalized and non-glottalized vowels may be fluctuated by the individual characteristics of speakers.

On the other hand, the formant structure of some non-glottalized vowels carrying high tone /55/ is very similar to that of glottalized vowels. For example, the frequencies of the first and second formants of /u 55/ in /vu 21 l u 55/ are 720 Hz and 1,570 Hz, respectively. These values are very closed to the mean value of the frequency of the first and second formants of mid tone /33/ glottalized vowels.

It can be observed from the formant structure that higher formants of glottalized vowels have rather stronger energy than that of non-glottalized vowels. The whole picture of spectrogram of glottalized vowels makes "quite darker" impression than that of non-glottalized vowels. This implies that glottalized vowels have a stronger acoustic energy than non-glottalized vowels.

3.2 Fundamental Frequency

As mentioned earlier, the Xi-de Yi Language has four types of tone, and the difference of tone makes a great influence on the value of fundamental frequency. To minimize the direct influence from tone, the materials of analysis are restricted to the vowels /u̱,ɔ̱,u,o/ carrying mid tone /33/.

There can be seen a fluctuation in the fundamental frequency value even within a vowel, and the maximum value in a vowel was adopted as the basis for analysis. The results can be shown in Table 2. The mean values of the fundamental frequency of glottalized vowels /u̱/ and /ɔ̱/ are 189.6 Hz and 195.9 Hz, respectively. On the other hand those of non-glottalized vowels /u/ and /o/ are 200.8 Hz and 204.0 Hz, respectively.

The results show the tendency that fundamental frequency of glottalized vowels is slightly lower than that of non-glottalized vowels. It is generally known that the tension of the vocal folds causes increase of fundamental frequency, and, furthermore, that the more the glottal stricture is closed, the more frequently the low pitch occurs (Ladefoged, 1973). From physiological points of view, it is also known that the lowering of larynx, the decrease of subglottal air pressure, or the movement of the laryngeal muscles has direct effect on the lowering of fundamental frequency. The lowered Fo in glottalized vowels in Lolo may imply that these vowels can be characterized not by glottal tension, but by glottal constriction. Therefore, it can be inferred that glottalized vowels have the same property as the creaky vowels have.

Table 2. Fundamental Frequency of /u̱,ɔ̱,u,o/

	Vowel	Fo (Hz)	Word Context	Meaning
glottalized vowels	/u̱/	200	/nu̱ 33 ma̱ 33/	soybean
		195	/the̱ 44 du̱ 33/	outstanding (出色)
		192	/ku 44 hu̱ 33/	cheer
		190	/mu 33 tʂhu̱ 33/	autumn
		185	/lu̱ 33 khu̱ 33/	city
		185	/lu̱ 33 khu̱ 33/	city
		180	/nɔ̱ 33 bu̱ 33/	black pattern (黒花色)
	/ɔ̱/	220	/tsha̱ 44 ɬɔ̱ 33/	warm
		205	/nɔ̱ 33 su 33/	the Yi tribe
		200	/nɔ̱ 33 bu̱ 33/	black pattern (黒花色)
		200	/za̱ 33 hɔ̱ 33/	talented
		185	/ȵɔ̱ 33 tsi 33/	eyelashes
		181	/ɣa̱ 33 nɔ̱ 33/	back
		180	/ŋa̱ 21 nɔ̱ 33/	bitter buckwheat noodles (苦蕎)
non-glottalized vowels	/u/	210	/mu 33 ɬɿ 33/	wind
		210	/xo 55 phu 33/	crowd
		200	/thi 33 pu 33/	water pail
		200	/lu 33 pɿ 44/	maxim
		195	/nɔ̱ 33 su 33/	the Yi tribe
		190	/mu 33 tʂhu̱ 33/	autumn
	/o/	215	/n̥i 44 lo 33/	crimson
		210	/dʐo 33 dʐu 44/	life
		187	/ko 33 mo 44/	beginning

3.3 Amplitude and Duration

Amplitude is also influenced by the type of tone. The higher the tone is, the stronger the amplitude is. As is generally known, the amplitude is subject to variation to the recording and reproducing level. With these conditions in considerations, it can be said that the amplitude of glottalized vowels is slightly stronger than that of non-glottalized vowels.

From the vowels pronounced in isolation, it was observed that the rising of onset in glottalized vowels /e̠, a̠, ɔ̠/ was quite sharp. Also it was observed that the fluctuation of amplitude in glottalized vowels /u̠/ and /ɿ̠/ was remarkable.

As to the duration, there is a tendency that a vowel carrying higher tone also has a longer duration. From the vowels carrying mid tone /33/, it can be observed that the duration of glottalized vowels is slightly longer than that of non-glottalized vowels.

3·4 Relative Intensity of higher harmonic components

From the survey of wide-band and contour display analysis, it was observed that a higher frequency range of glottalized vowels has rather a stronger acoustic energy in comparison with non-glottalized vowels. Therefore, it seems necessary to examine the relative intensity of higher frequency range.

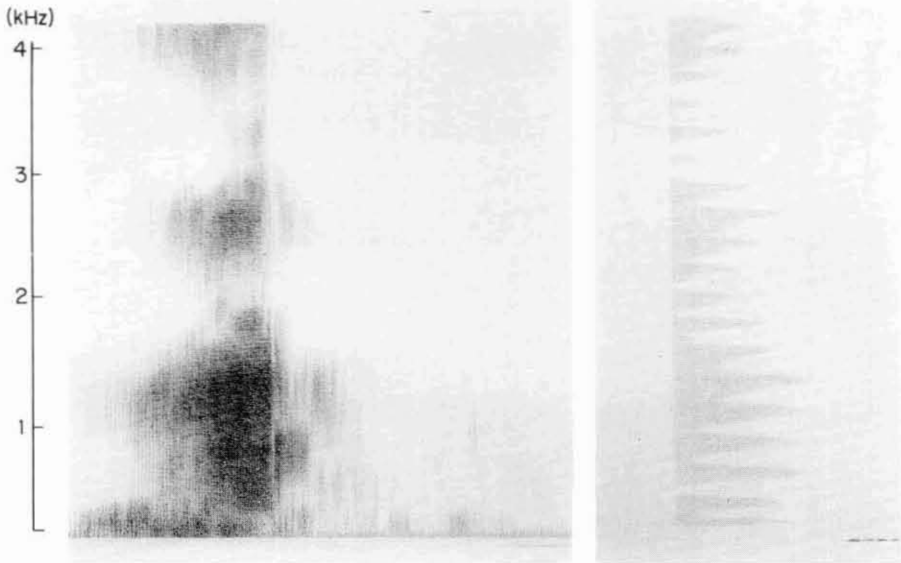
Instead of seeking the spectrum envelope[4], the mean value of relative intensity of higher harmonic components of a given range was compared with that of the lower range. In this analysis, the frequency range from 3,500 Hz to 4,000 Hz was assumed to be higher frequency range, while the frequency range under 500 Hz was supposed to be a lower one.

By subtracting the mean value of the relative intensity of the harmonic components of higher frequency range from that of lower frequency range, it can be estimated to what extent the relative intensity of higher harmonic components varies. The less the difference is, the stronger the relative intensity of higher harmonic components is. It means that the decrease of energy in a higher frequency range is small.

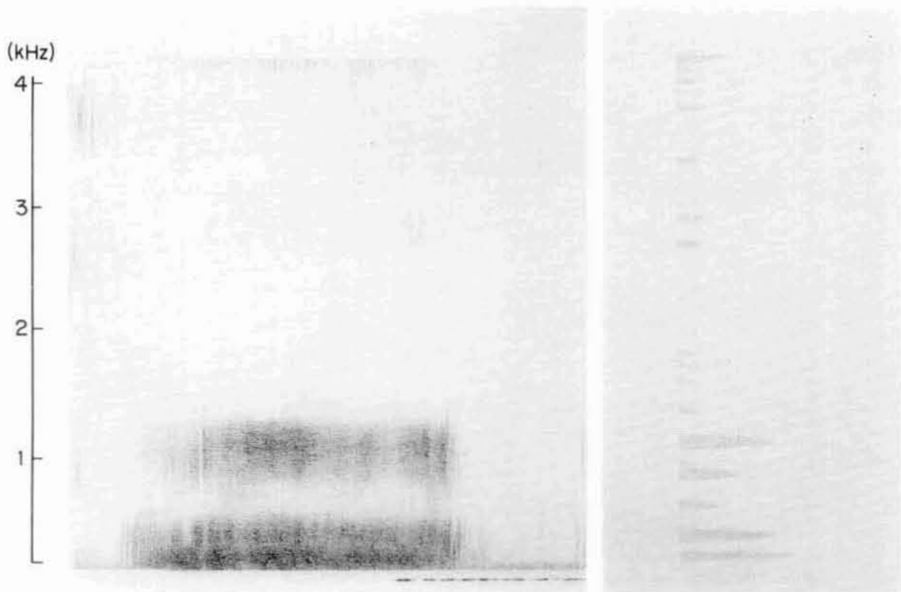
The results can be shown in Table 3. The mean values of the estimated relative intensity of glottalized vowels /u̠/ and /ɔ̠/ are 10.9 dB and 12.3 dB, respectively. Those of non-glottalized vowels /u/ and /o/ are 24.3 dB and 31.7 dB, respectively. These results indicate that glottalized vowels have quite a stronger relative intensity in the higher harmonic components. One of the reasons for this is that the energy of higher formants at the third, the fourth or the fifth formant of glottalized vowels is stronger than that of non-glottalized vowels. It can be observed that there is a tendency that at least one of the higher formants belongs to the frequency range from 3,500 Hz to 4,000 Hz. In the case of glottalized vowel /ɔ̠33/ in /n̥ɔ̠33 tsi 33/, as there is no higher formant in this frequency range, relative intensity of higher

4) Imaizumi et al. (1980), p. 13.

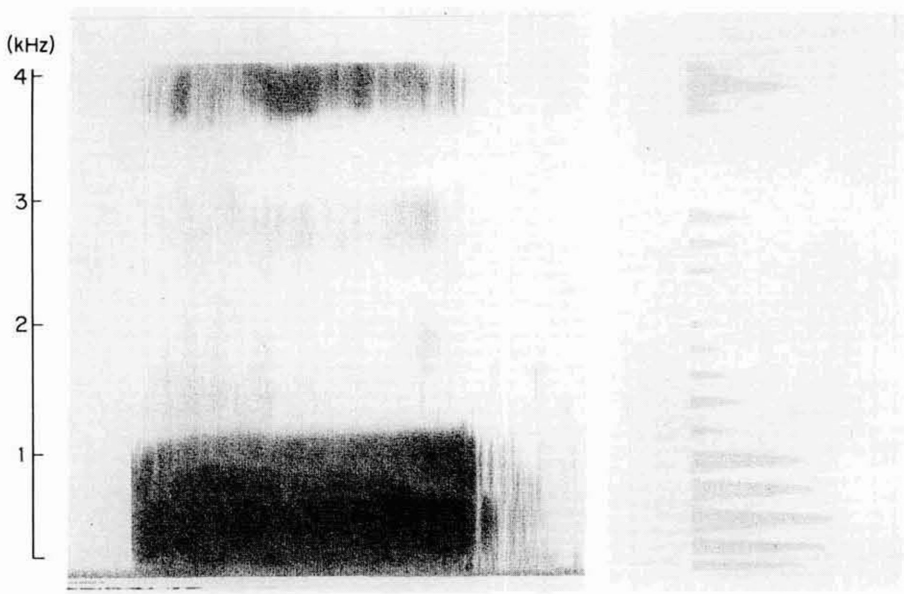
Examples of the soundspectrogram



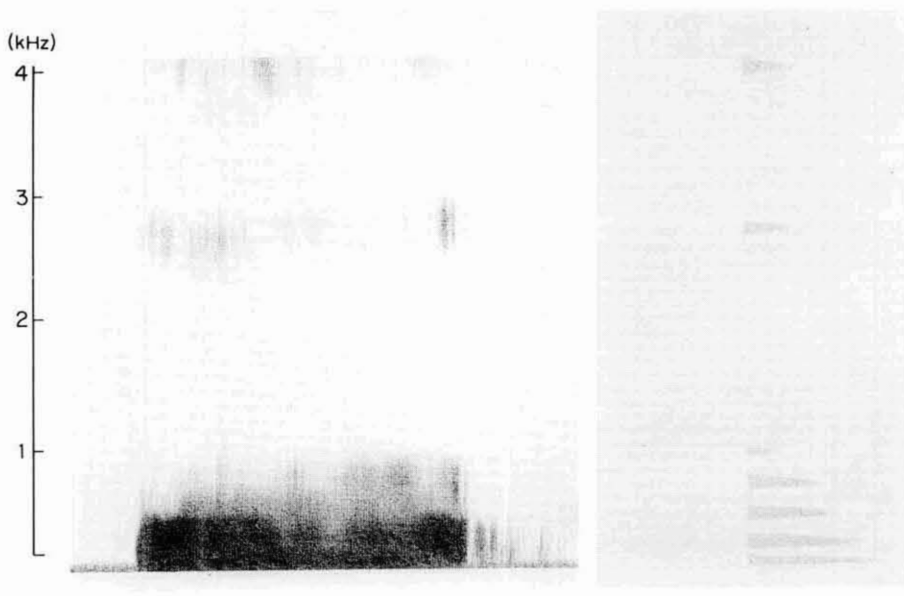
Glottalized vowel /u̲/



Non-glotta ized vowel /u/



Glottalized vowel /ɔ/



Non-glottalized vowel /o/

Table 3. Examples of relative intensity of harmonic components

	Vowel	IL (dB)	IH (dB)	(IL-IH) IE (dB)	Word Context	Meaning
glottalized vowels	/u̱/	30.0	22.0	8.0	/nu̱ 33 ma̱ 33/	soybean
		23.5	14.5	9.0	/mu 33 tʂhu̱ 33/	autumn
		21.5	12.0	9.5	/lu̱ 33 khu̱ 33/	city
		21.5	11.7	9.8	/ku 44 hu̱ 33/	cheer
		26.0	15.3	10.7	/nɔ̱ 33 bu̱ 33/	black pattern (黒花色)
		27.5	16.0	11.5	/lu̱ 33 khu̱ 33/	city
		28.5	11.0	17.5	/the̱ 44 du̱ 33/	outstanding (出色)
	/ɔ/	24.0	23.0	1.0	/ŋga̱ 21 nɔ̱ 33/	bitter buck wheat noodles (苦蕎)
		24.0	12.7	11.3	/tsha̱ 44 ɬɔ̱ 33/	warm
		28.0	15.7	12.3	/za̱ 33 hɔ̱ 33/	talented
		32.5	19.7	12.8	/nɔ̱ 33 bu̱ 33/	black pattern (黒花色)
		29.5	16.7	12.8	/nɔ̱ 33 su 33/	the Yi tribe
		33.0	20.0	13.0	/ɣa̱ 33 nɔ̱ 33/	back
		29.0	6.0	23.0	/ȵɔ̱ 33 tsi 33/	eyelashes
			(*17.3	*11.7)		
non-glottalized vowels	/u/	30.0	11.3	18.7	/mu 33 tʂhu̱ 33/	autumn
		29.5	8.0	21.5	/mu 33 ɬl 33/	wind
		33.0	11.0	22.0	/xo 55 phu 33/	crowd
		27.5	2.7	24.8	/nɔ̱ 33 su 33/	the Yi tribe
		31.0	5.7	25.3	/thi 33 pu 33/	water pail
		33.5	0.0	33.5	/lu 33 pl 44/	maxim
		30.0	1.3	28.7	/ko 33 mo 44/	beginning
		31.5	0.0	31.5	/dʑo 33 dʑu 44/	life
		35.0	0.0	35.0	/n̥i 44 lo 33/	crimson

* shows the value which the frequency range from 4,000 Hz to 4,500 Hz was adopted as higher frequency range.

IH : The mean value of relative harmonic components of higher frequency range (3,500 Hz to 4,000 Hz).

IL : The mean value of relative harmonic components of lower frequency range (under 500 Hz).

IE : The estimated value of relative intensity of higher harmonic components (IL–IH).

components is rather weak. However, when the frequency range from 4,000 Hz to 4,500 Hz is examined, relative intensity shows a stronger value. In the case of non-glottalized vowels, as the energy of higher formants is quite weak in itself, the movement of the basis for the higher frequency range could not make almost any influence on the estimate of relative intensity in the higher harmonic components.

Another reason may be the noise perturbation caused by the glottal constriction of glottalized vowels. The frication by respiration at the glottis makes noise, and the energy of this noise reflects the intensity of higher frequency range.

Some high tone /55/ non-glottalized vowels also have quite a stronger relative intensity in the higher harmonic components. For example, the estimated value of relative intensity of higher harmonic components of non-glottalized vowel /u55/ in /vu21lu55/ is quite similar to that of glottalized vowel /u̲/. The similar property between non-glottalized vowels carrying high tone /55/ and glottalized vowels suggests that the opposition between glottalized and non-glottalized vowels is quite weakened in these high tone /55/ types. There are no high tone /55/ glottalized vowels /u̲, ɔ̲/ in the materials of the present study, but there can be found some high tone glottalized vowels /e̲, a̲/. It seems necessary to investigate further research on this point.

4. SUMMARY

From the spectrographic analysis on glottalized vowels in Xi-de Yi, some acoustic properties can be clarified as following. From the examination of formant structure, it appears that glottalized vowels have a higher frequency of the first formant. As mentioned esrlier, Nishida (1979) pointed out that the tongue height of glottalized vowels in Lolo is rather lower than that of non-glottalized ones. This articulatory property is, therefore substantiated in terms of primary acoustic correlates, since tongue height is inversely related to the first formant. Fundamental frequency analysis shows that they are slightly lower in pitch. This implies that they are articulated with a glottal constriction, not with glottal tension. From the amplitude analysis, it was shown that glottalized vowels have a slightly stronger amplitude and the onset of them rather sharp. It was also indicated that glottalized vowels have a slightly longer duration by means of the durational analysis. From the section analysis it can be concluded that glottalized vowels have considerably stronger relative intensity of higher harmonic components. These demonstrate that glottalized vowels have a stronger prominence than non-glottalized vowels. Further elaboration is necessary to clarify the nature of prominence of the vowels.

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